PC-Based Instrumentation for Versatile Applications Advantages, Implementation Challenges and Combating Techniques

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Abstract: Personal Computer (PC) based instrumentation has a wide range of applications in the field of education and research. The wide variety, high performance, and reasonable cost of both commercial hardware and software make this platform an attractive choice for instrumentation. Although PC-based instrumentation offers significant advantages, it also has technical obstacles and significant implementation challenges for high-performance test and measurement applications. This paper presents the advantages of PC-based instrumentation and identifies the technical limitations to implement a high-performance system for versatile applications. The methods of combating the inherent problems associated with the PC-based instrumentation have also been presented. The paper suggested an implementation method for PC-based instrumentation which is based on Virtual Instrumentation (VI) technique and PXI architecture. This method enhances the system implementation productivity and lowers the cost through easy-to-integrate LabVIEW software and PXI modular hardware. An application example of an implemented large slot-count PC-based instrumentation system has also been presented. This system has been developed at NWTF, IIT Kanpur for automated wind tunnel testing.

Keywords: PC-based instrumentation, LabVIEW, PXI-architecture, virtual instrument, wind tunnel.

1. Introduction

The majority of today's traditional test and measurement instruments and expensive data logging equipment are destined to become museum pieces as PC-based instruments make their way into research and development, engineering, industrial applications and ultimately the home. In the past, conventional instruments, such as oscilloscopes and spectrum analyzers, were available only as expensive, bulky bench-top products. Similarly, data acquisition and logging required personalized hardware and software solutions, and was often prohibitively expensive for low-end applications. Then, in the early 1990s, PC-based instrumentation appeared on the scene and test and measurement and data logging changed forever. Data acquisition could now ride on the back of the PC industry, reaping the benefits of low cost and standardized user interfaces. In addition, we saw the dawn of virtual instruments (VIs): comprising software and hardware elements which enable conventional PCs to be used as data loggers, oscilloscopes, spectrum analyzers and/or multi-meters.

This paper presents the advantages of PC-based instrumentation and identifies the technical challenges to implement high-performance instrumentation system. The methods of combating the inherent problems associated with the implementation of PC-based instrumentation have also been presented.

Advantages of PC-based Instrumentation

Most of the benefits of PC-based instrumentation are well known and include portability, large colour displays, fast processors, disk drives and printers. True, all are available on traditional bench-top instruments but only on the high-end (and

high price) models or as expensive accessories. The wide variety, high performance, and reasonable cost of both commercial hardware and software make this platform an attractive choice for instrumentation. The high performance and low cost of this platform usually compares favorably to custom and industrial bus based solutions. In addition to the hardware advantages, a very large selection of off the shelf software exists for this platform. In addition to the obvious choices of operating systems, a variety of commercial application development environments, control system toolkits, and system utilities are available. These resources facilitate efficient development of intelligent instrumentation.

Another of PC-based instruments' called VIs' key advantages is that the PC can utilize common hardware for different software tools - in other words it can be more than one instrument at any one time. Other benefits include the fact that data can be exported to spreadsheets and that data can be 'pasted' straight into reports. In addition, with the growth of e-mail and the power of the Internet, engineers can transmit waveforms, traces and readings from site to site, via their portable PC, for further analysis.

PC-based Instrumentation and Its Applications

PC-based instrumentation has led to a simpler way of looking at measurement systems. Instead of using several stand-alone instruments for multiple measurement types and performing rudimentary analysis by hand, scientists and engineers from any discipline now can quickly and cost-effectively create a system equipped with analysis software and a single measurement device that has the capabilities of a multitude of instruments. As shown in Figure 1, a basic PC-based instrumentation system consists of a PC installed with operating system and data acquisition board, test and measurement hardware and application software. This platform has the capability to serve the test, measurement and control applications of all the fields of science and engineering as illustrated in Figure 1.

2. Implementation Challenges

When packaging an instrument in the PC form factor, several issues need to be addressed. The most limiting feature of the PC for multiple numbers of data acquisition board installations is the limited numbers of available PCI (Peripheral Component Interconnect) slots on its motherboard. Current PCs utilize the PCI bus as the standard in-box I/O standard, and since the PC was not designed as an instrumentation platform, electrical noise and power supply regulation is often problematic. Since PC enclosures are designed for computers, several analog isolation issues exist. In general the PC power supply regulation and power are inadequate for multiple precision analog measurements.

3. Combating Techniques

PCs are an excellent test and measurement platform for low to medium slot-count applications. Most PCs offer two to three PCI slots and are not suitable for high slot-count applications. More peripheral slots can be added through the use of PCI-to-PCI bridges. But more than three bridges on one PCI bus degrade the performance of the bus and prevent the use of multiple high-performance measurement and control devices in one system. This problem can be solved by using PCI extensions for **I**nstrumentation (PXI) platform [1], which offers all the benefits of the PCI architecture. PXI is a modular

instrumentation platform designed for measurement and automation applications

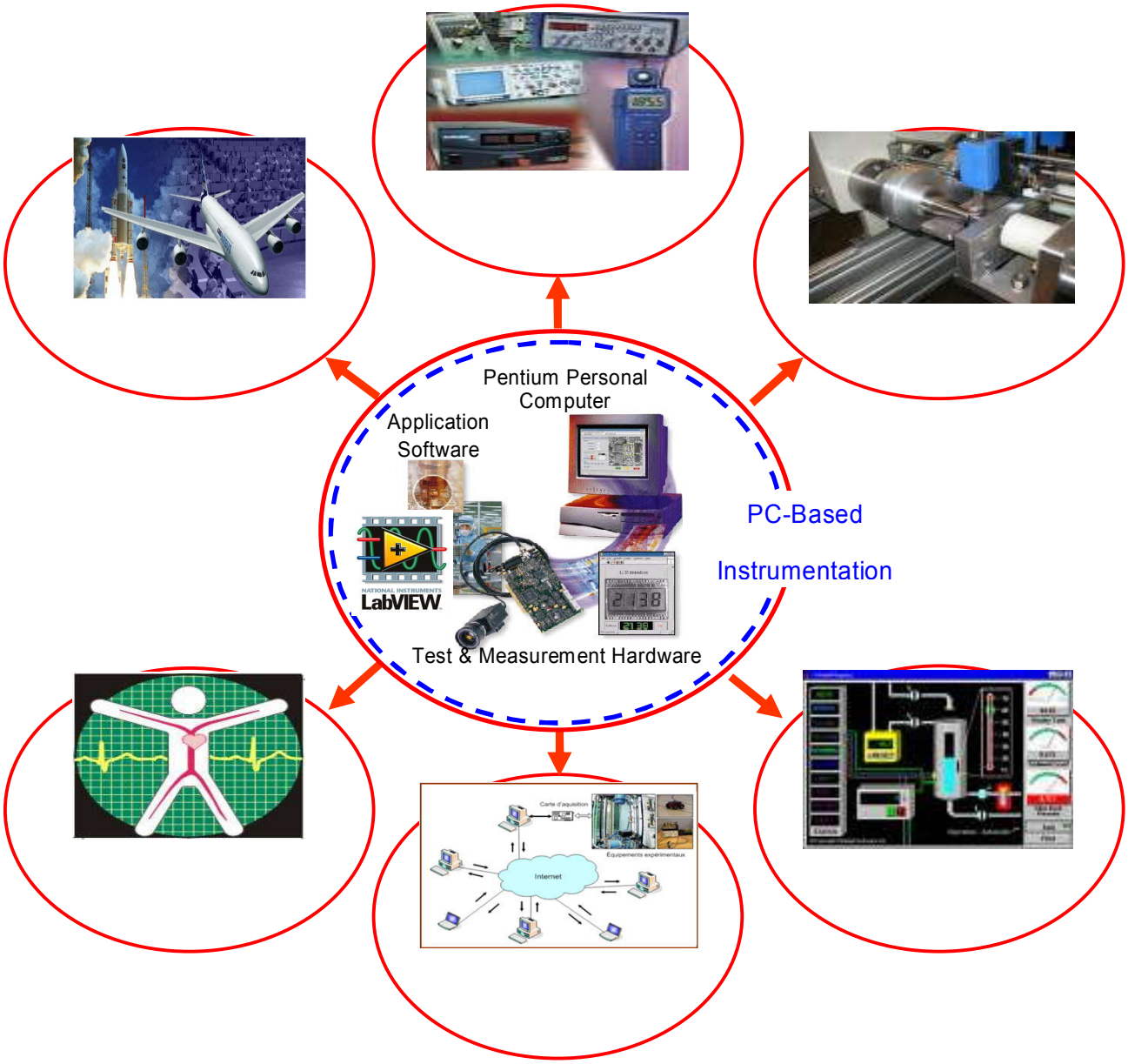

Figure 1: PC-Based instrumentation and its versatile applications

that require high-performance, low-cost deployment solution and a rugged industrial form-factor. Because PXI system has more peripheral slots per bus segment, it is possible to build high-slot-count systems without sacrificing a high-performance bus. The PXI architecture also meets the more specific needs of instrumentation users by adding an integrated trigger bus and reference clock for multi-board synchronization. By using PXI architecture which has its high performance built-in power supply, the problem of insufficient regulation and available power of DC supply power of PCs is automatically solved.

When implementing a PC-based instrumentation using PXI system, choosing the right system architecture is very important.

The system architecture will affect not only the actual performance of a system, but also the ability to expand the system in future. There are various architectures to choose from based on the application needs. One of the key benefits of using the PC-based modular PXI platform is that there is almost no software change required if the user wants to move from one system architecture type to another due to changes in his applications or future expansion. This section discusses various architectures of PXI-based instrumentation system which are classified on the basis of number of slot-count requirement for the system application.

3.1 Medium Slot-Count Application Architecture

One way to achieve lower cost and high performance for PC-based instrumentation is to use a PXI chassis controlled by an external desk-top PC or laptop (Figure 2). The National Instruments PXI-1033 low-cost five slot chassis with integrated controller is available for medium slot-count remote control applications [2]. With a built-in MXI (Measurement eXtensions for Instrumentation)-Express controller in the PXI chassis and MXI interface kit, users can control PXI systems directly from desktop or laptop computer. During boot-up, the computer will recognize all the peripheral modules installed in the PXI chassis as PCI/PCI Express devices because the links are transparent to software application and drivers. The PXI-1033 system kit includes the PXI chassis with integrated MXI-Express controller, a host card, and a cable. The host card may be either a PCI_e-8361 PCI Express board for desktops or a PXI_e-8360 ExpressCard for laptops. The PXI-1033 chassis features low-cost high performance, compact, rugged packaging as well as acoustically quiet operation, which makes it ideal for both portable and desktop ATE systems. With an integrated MXI-Express controller in the chassis, the PXI-1033 provides a transparent, remote link with up to 110 MB/s sustained throughput.

3.2 Large Slot-Count Applications Architecture

A way to achieve large slot-count high performance application for PC-based instrumentation is to use National Instruments (NI) large slot-count PXI-1042 (eight slots) and PXI-1043 (seventeen slots) PXI architecture controlled by an external PC. The NI PXI-PCI833x interface kits give PCs direct control of PXI systems using MXI-4 [3] technology. With a MXI-4 link, user can transparently control a PXI system from any PCI slot, so high-performance desktop computers can control PXI systems. Because PXI is based on the industry-standard PCI bus, MXI-4 provides a transparent link where all PXI modules installed in the PXI chassis appear to the user as if they were PCI boards within the computer itself. However, user benefit from the increased number of slots, power and cooling per slot, module selection, and synchronization features provided by PXI. Additionally, with fiber-optic MXI-4 user can electrically isolate his PXI measurement hardware from the PC with extended length cabling up to 200 m. The MXI-4 link consists of a PCI-8331 (copper) or PCI-8336 (fiber-optic) board in the PC, connected via the appropriate cable to a PXI-8331 (copper) or PXI-8336 (fiber-optic) module in slot 1 of a PXI chassis. Figure 3 shows the schematic diagram of a high slot-count high-performance PXI-based instrumentation system implemented at National Wind Tunnel Facility (NWTF), IIT Kanpur. The system uses eight slot PXI chassis (PXI-1042) installed with PXI-8336, MXI-4 interface module and required PXI modules for data acquisition and motion control applications. National Instruments MXI-4 fibre-optic interface system used in this work offers the flexibility

to integrate high performance desktop PC with the PXI system 30 meter away on the experimental floor in electrically noisy environment.

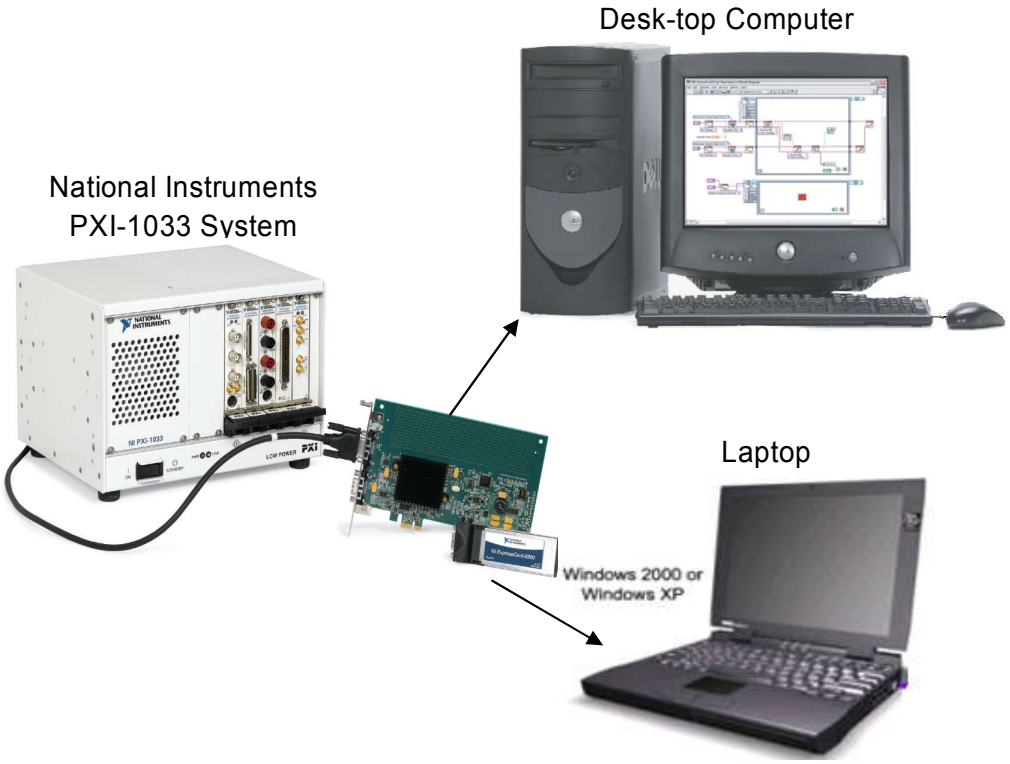

Figure 2: Low-cost medium slot-count PXI-based instrumentation system

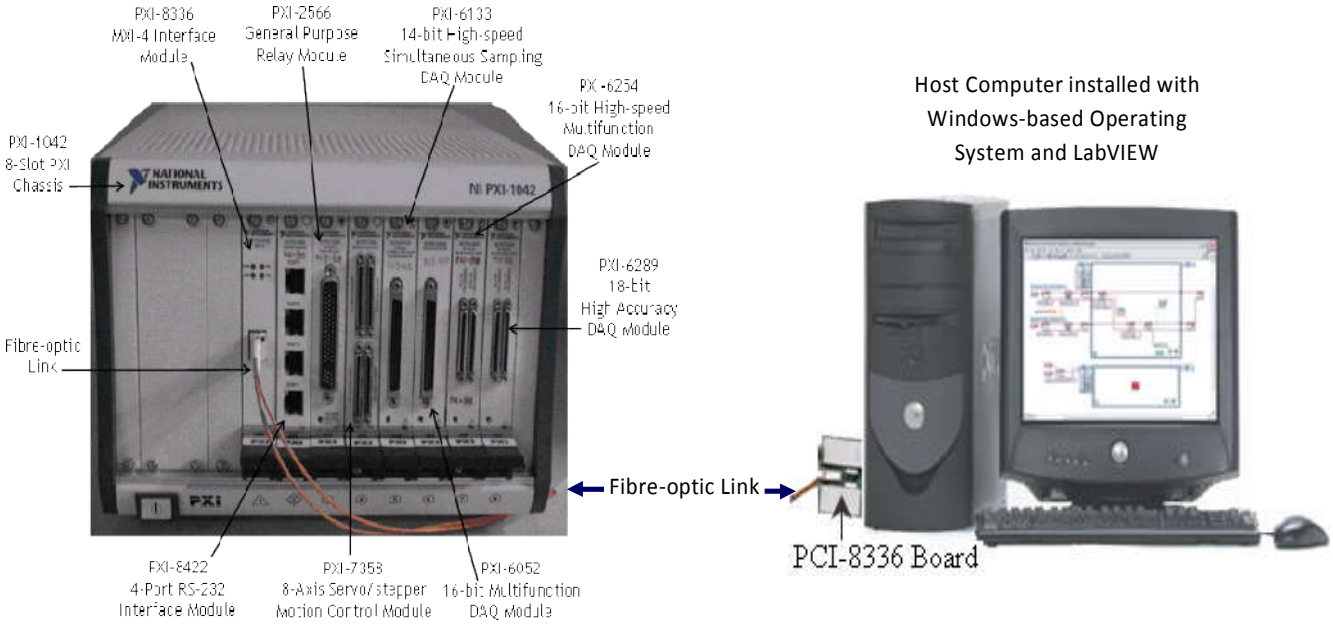

Figure 3: A large slot-count high-performance PXI-based instrumentation system

3.3 Very Large Slot-Count Applications Architecture

PC and Laptop control of PXI architectures are all limited by the number of slots available in a single PXI chassis, but many high slot-count applications require more than the 17 modules usable in the largest NI PXI-1045 chassis. One way to increase the channel count of the system is adding more PXI chassis to the system. Additional chassis can be added with MXI-4 in either a daisy-chain or star configuration.

Selection of Application Software

The software in the Application Development Environment layer provides the tools to develop the code or procedure for the application. For the PCI-based instrumentation using PXI architecture, the application software is developed using virtual instrumentation technique. This application software is named as virtual instruments (VI). For the presented work, the VIs are developed using NI LabVIEW-based graphical development platform [4]. This enables the user to create instruments with "pick and place" icons and hence increases productivity and lowers the development costs.

Application Example of A Large Slot-Count PC-Based Instrumentation System

National Wind Tunnel Facility (NWTF), IIT Kanpur has a closed circuit wind tunnel with unique and internationally recognized capabilities to evaluate aerodynamic performance of flight and road vehicles as well as wind effects on civil structures. A versatile PC-based wind tunnel instrumentation system [5] as shown in Figure 4 has been implemented at NWTF using large slot-count PXI architecture. The hardware of the PXI-based wind tunnel instrumentation system mainly consists of a NI MXI-4 (PXI-PCI-8336) interface kit, a PXI system and a Pentium-IV host computer running Windows XP. An eight slot PXI-chassis installed with a PXI-8336 (MXI-4 Interface) board and the required measurement and control modules is placed in the instrumentation room just below the wind tunnel test section. This helps to improve the acquired test data quality significantly by minimizing the cable lengths connecting the instrumentation system to the model instrumented with sensors. Windows–based host computer installed with a PCI-8336 MXI-interface board and LabVIEW software is placed in the NWTF control room. The PXI system is controlled directly from the host computer with a transparent, high-speed fibre-optic link. The implemented system features a closed-loop control system integrated with the data acquisition system for repeatable and efficient conduct of wind tunnel testing at wind speeds of up to 80 m/sec.

The PXI-System used for the implementation of the wind tunnel instrumentation system has been configured using LabVIEW-based application software to perform all the conventional data acquisition and control tasks for wind tunnel test applications. The major applications include the measurement and control of the wind tunnel test section speed, remote ON-OFF control of power supplies/systems and electrical drives located in the instrumentation room using control room host computer, multi-port model surface pressure measurement, strain-gauge based pressure and force measurement experienced by the model, model angle (pitch/roll) measurement, ambient/test section temperature, atmospheric humidity and pressure measurement, and model attitude control using multi-axis motion control system. Figure 5 shows the simplified diagram of the PXI-based integrated instrumentation system to implement all the above mentioned tasks.

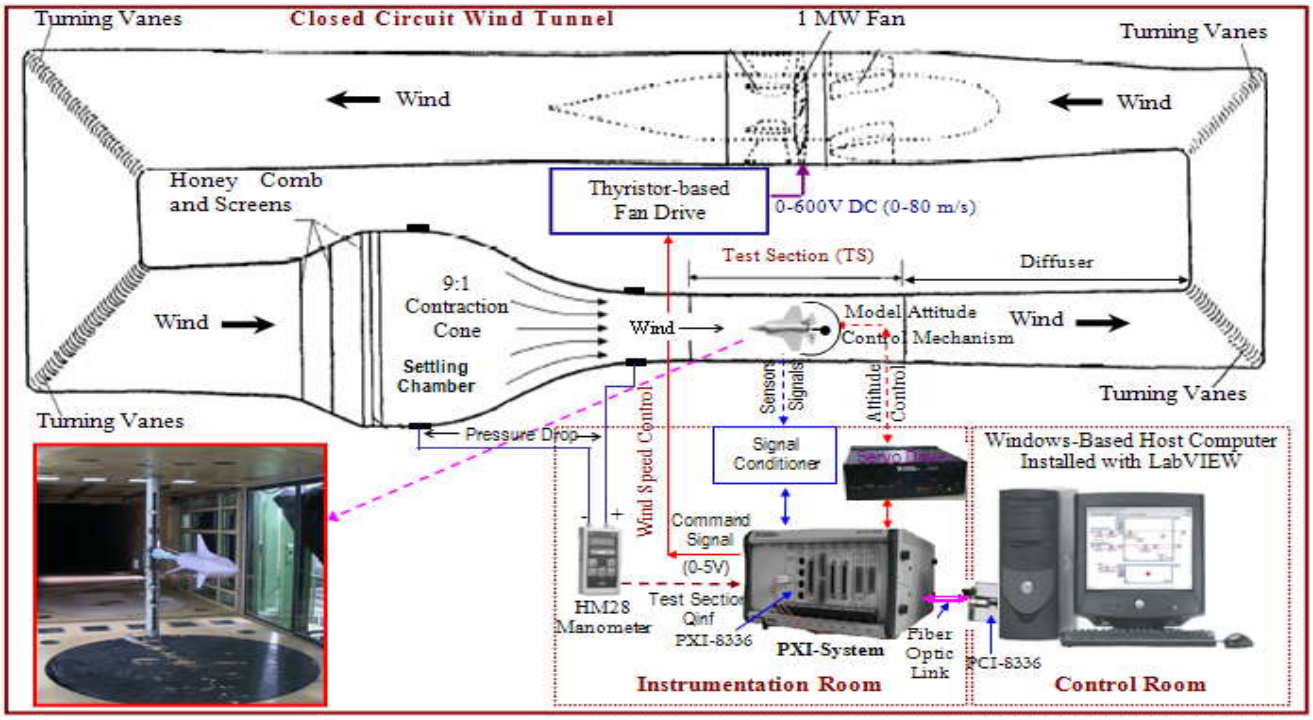

Figure 4: Schematic diagram of a versatile PC-based wind tunnel instrumentation system

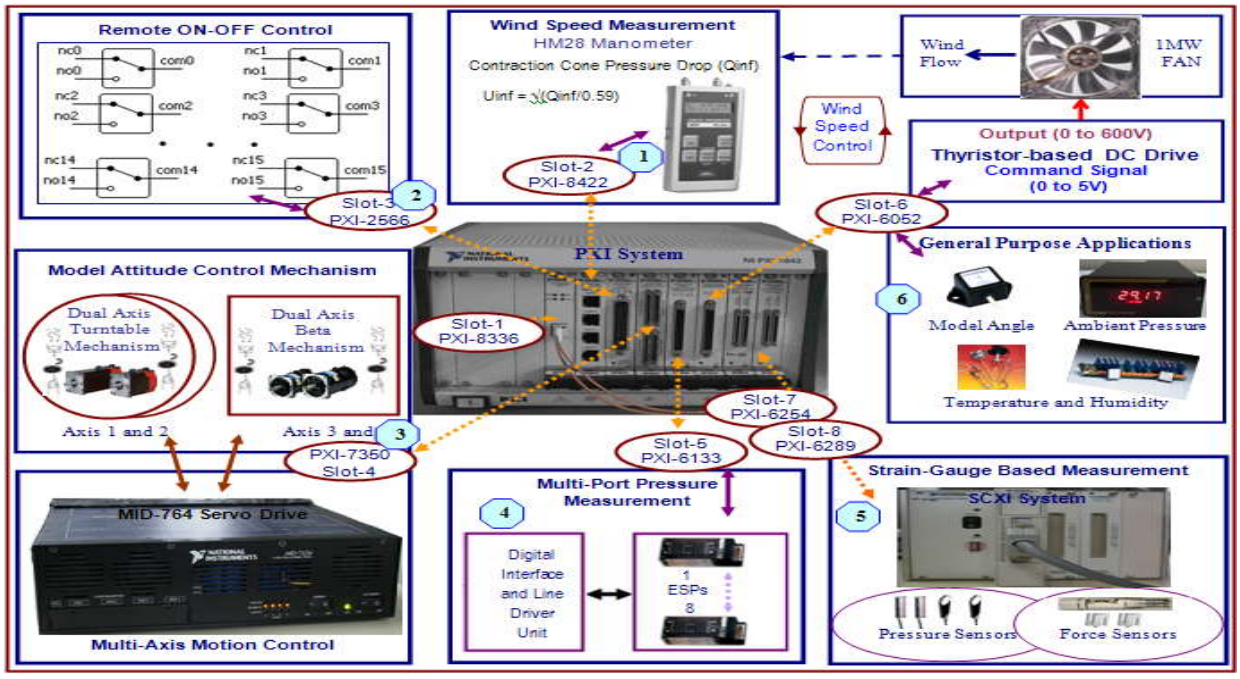

Figure 5: PXI-based integrated instrumentation system for automated wind tunnel testing

4. Conclusions

The PC is an attractive platform for instrumentation development, and will become more so in the near future. This paper has presented the advantages of PC-based instrumentation and identifies the technical limitations to implement high-performance system for versatile applications. The methods of combating the inherent problems associated with the PC-based instrumentation have also been presented. The suggested implementation technique of PC-based instrumentation system in this paper is based on Virtual Instrumentation (VI) technique and PXI architecture which enhances the productivity and lower the cost through easy-to-integrate LabVIEW software and PXI modular hardware. This paper also presented an application example of an implemented large slot-count PC-based instrumentation system which has been developed at NWTF, IIT Kanpur for automated wind tunnel testing.

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